CVD DIAMOND COATING OF INTERIOR SURFACES

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Abstract

There are several applications where the interior surfaces of tools or parts need low friction and have to be protected against wear. Cases in point are dies for drawing wires. Top quality dies for the fabrication of wires are made of monolithic diamond or at least sintered polycrystalline diamond (PCD). Especially tools made of monolithic diamond have excellent wear resistance and low friction coefficients. These properties allow the fabrication of wires with high degree of precision of the diameter and excellent surface smoothness. In addition to that wires can be produced with high operating speed applying water suspensions as lubricant. In some cases even dry production is possible. However, especially for larger diameters high prices limit the use of diamond dies. Another limitation is the restriction to almost circular shapes. Coating of the interior walls of drawing dies with thin polycrystalline diamond films is a solution for utilizing the superior properties of diamond beyond these limitations of costs and geometries.

In a co-operation of four Fraunhofer Institutes and tool makers we investigated hot-filament chemical vapor deposition (HF-CVD) of diamond coatings on silicon-based ceramics. We have demonstrated high adhesion levels of the diamond coatings even on polished substrate surfaces [1]. Surface roughening to enhance adhesion, a typical pretreatment in the case of diamond coatings on cemented carbide, is not necessary. This is obviously due to the formation of chemical bonds between carbon atoms from the diamond and silicon atoms from the ceramic substrate at the diamond-substrate interface. Additionally, no binder material like cobalt has to be removed by laborious etching procedures which are cost effective and also influence the substrate surface roughness. Thus the surface roughness is dominated by the diamond film roughness.

In the case of drawing dies the deposition of well adherent smooth diamond coatings on polished substrate surfaces is a prerequisite to achieve the surface quality for drawn wires. To realize diamond coated drawing dies this concept has to be combined with a deposition process for interior coating.. Therefore we have investigated several versions of the HF-CVD technique to evaluate the possibilities for interior wall diamond coating. At special process conditions the deposition of diamond films is demonstrated for cylinders with inner diameters ≥ 2 mm and aspect ratios of up to 10. The film thickness distribution and morphology of the coatings was characterized by scanning electron microscopy.

Cylindrical substrates with relatively large diameters and aspect ratios can be coated by placing a hot filament for gas activation inside the substrate [2,3]. However, for typical drawing die geometries the additional expense for filament and substrate arrangement is not necessary. For drawing dies with diameters above 4 mm the diamond deposition is realized at low process pressures under diffusion controlled conditions. In this case the substrates can be coated in a deposition process which is more economic than placing the filaments inside an arrangement of dies.

For dies with diameters below 4 mm the interior coating has been realized by transporting the activated gas into the orifice of the drawing die by means of a directed gas stream (cf. figure 1). By applying this technique from both sides of the substrates, successively, almost homogeneous diamond films for aspect ratios length/depth ≥ 10 are possible. However, for drawing dies a single deposition step from one side of the drawing tool is sufficient (cf. figure 2).

In general, the diamond crystal size, which is correlated to the film roughness, decreases with increasing deposition depth. In the case of drawing dies, this effect results in smooth diamond coatings in the area of smallest diameter, which is favorable for the production of wires with high surface quality.

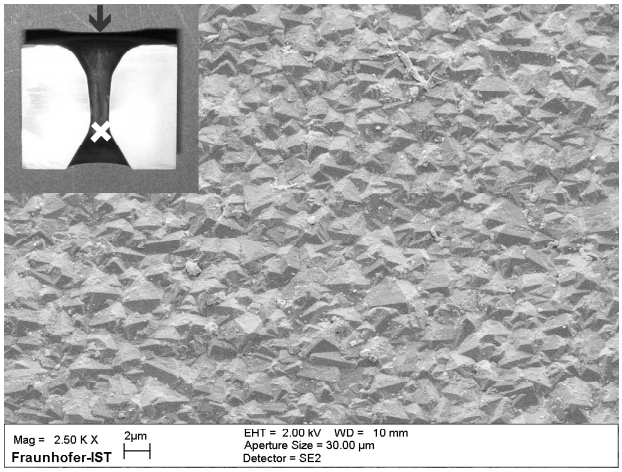

Figure 1. Diamond coated ceramic drawing die with 2 mm diameter produced by means of a directed gas stream. The small picture shows the sliced tool, the larger picture the morphology of the diamond film at the point of the lowest diameter (cross). At this point the film thickness is 6 µm compared to 10 µm at the gas inlet (arrow).

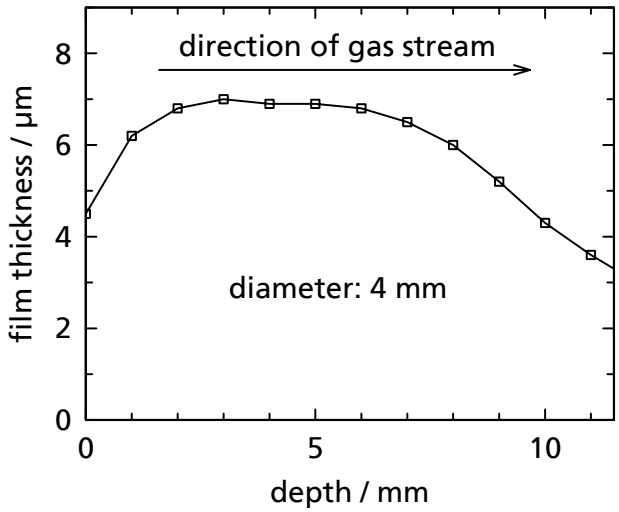

Figure 2. : Film thickness distribution in a cylindrical test geometry with 4 mm diameter. The activatd process gas is transported into the orifice by means of a directed gas stream resulting in diamond deposition on the interior surface.

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